Dynamic Earth
Field Trip Program

Grand Canyon Focus: Geology
School Subjects: Science, Reading, Writing, & Physical Activity
Grade Levels: 3rd – 7th
Duration: 5 hours (including walking time)
AZ Standards Addressed: (see list at end of lesson plan for details)

Science: Inquiry Process
- Observations, Questions, Hypotheses
- Scientific testing
- Analysis and Conclusions
- Communication

Earth and Space
- Properties of Earth materials
- Earth's Processes and Systems
- Structure of the Earth

Reading: Acquire and use new vocabulary in relevant contexts.
Writing: Applications – expressive writing
PA: achieve and maintain a health-enhancing level of physical fitness.
develop self-initiated behaviors that promote effective personal and social interactions in physical activity settings.

Specific standards are located after corresponding objectives and procedures listed below.
(Subject Grade- Strand Concept- Objective)

Theme
The dynamic geologic forces constantly at work in the world are displayed at Grand Canyon for all to experience.

Lesson Overview
Over billions of years, geologic processes such as deposition, uplift and erosion have shaped the surface of planet Earth. By studying the geologic history of Grand Canyon, students will gain a better understanding of many universal geologic principles and processes.

Lesson Objectives
Students will be able to:
1. Name the 3 rock types and how they form. (SC03-S6C1-02; SC07-S6C1-01; SC07-S6C2-02)
2. Describe the rock cycle by explaining how the surface of the earth is constantly changing (SC07-S6C2-01)
3. Explain what a fossil is. (SC03-S6C1-04; SC04-S6C2-06)
4. Explain what clues a fossil tells about ancient environments (SC04-S6C2-06; SC07-S6C1-04)
5. Identify rocks according to their characteristics using flow charts (SC07-S6C2-02)
6. Describe the different plate boundaries. (SC07-S6C2-03/05)
7. Explain what is responsible for erosion of Grand Canyon and how erosion works (SC04-S6C2-01/03; SC07-S6C1-03)

Materials
- Dynamic Earth Booklets
- First Aid Kit
- Optional: colored pencils

Program Procedures

Stop 1 – Program Overview & Safety Orientation

Objectives: Students will be able to:

- Describe the basic elements of the program
- Follow the required safety precautions of walking along the rim trail

Procedure:

- What does dynamic mean? How is nature dynamic? How might one recognize the effects of those forces?
- The program is a 1-mile walk with four stops for activities along the way. We will discuss and see the effects the dynamic forces of nature, have time for your personal reflections (W04/05/06/07-S3C1-02), and journal keeping.
- Safety briefing and behavior expectations. (Running, rock-throwing, squirrels, on-trail, with chaperones/parents, water, sunscreen).

Stop 2– Fossil Identification Activity

Objectives: Students will be able to:

- Explain the concept of geologic time versus regular time (SC07-S6C1-04)
- Define environment
- Explain the value of recording observations in a journal (SC03/04/05/06/07-S1C2-05)
- Make inferences to determine the environment that was present during Kaibab formation (SC04-S1C3-02)

Activity: Fossil hunt

Procedure:

- Explain that we will be paleontologists to study past environments.
- Define fossil. Describe fossil formation and have students point out a nearby fossil and guess what it is. (SC03-S6C1-04)
- Fossil activity: Identify fossils (SC06-S1C2-03), sketch two or three, and hypothesize/infer what crinoid looked like with its soft parts. (SC04-S1C3-02)
- Wrap up: Discuss what scientists know about this environment.(SC04-S1C3-02; SC04/05-S1C4-01; SC05-S1C4-03; SC06-S1C4-03; SC06-S1C4-05)

Stop 3– LUNCH

Stop 4– Geologic Time and Layer Formation:

Objectives: Students will be able to:

- List the three rock types (classifications) (SC03-S6C1-02; SC07-S6C2-02)
- Describe how they are formed (SC03-S6C1-02; SC07-S6C1-03)
- Discuss different observations used to classify rocks (color, hardness, crystals, sediment type, etc.) (SC03-S6C1-03; SC07-S6C1-01)
- Describe different environments that deposited the sedimentary rocks.(SC03-S6C1-02)

Activity: Rock boxes, rock identification

Procedure:

- Introduce oldest and youngest layers (law of superposition).
- Ask students what rocks are made of and describe rock types (SC03-S6C1-02; SC07-S6C1-03).
- Discuss rock types, textures, colors using rock boxes and posters. Let students find rougher and smoother samples and try to match the layers in the canyon to the samples in the rock box.

Stop 5– Plate Tectonics

Objectives: Students will be able to:

- Explain what plate tectonics is (SC07-S6C1-03, SC07-S6C2-03/05).
- Describe the different types of plate boundaries (SC07-S6C2-03/05).
- Identify the subductive boundary as the boundary that uplifted Grand Canyon (SC07-S6C2-03/05).

Procedure:

- Introduce plate tectonics. Ask what evidence we have of plate tectonics.
- Explain the layers of the Earth and how plate tectonics work. (SC03-S6C1-01; SC07-S6C1-03)
- Charades: explain the different boundary types and then give each group of kids a card. Have them act out their boundary and the others guess which it is (if time allows).
- Discuss that subduction made this area uplift but it uplifted differently to make the Colorado Plateau. There are still questions to be answered by future scientists.

Stop 6– The River Did It!

Objectives: Students will be able to:

- Explain the role of the river in the formation of the Grand Canyon as we see it today (SC04-S6C2-01/03)
- Describe how rain and snow make the canyon wider (SC04-S6C2-03)
- Define erosion (SC04-S6C2-01/03; SC07-S6C1-03)

Procedure:

- Do strongest force activity: Trust me to hit you with the strongest force in nature. Spray them with water.
- Did water do it alone? Debris in the river scrubbed away the rock and the river carried it away. (Use graph to demonstrate that the Colorado River gets its power from its high altitude headwaters).
- Ask them if the river is always the same color? What color is it now? What other color might it be? What would make it change colors?

Stop 7– Epilogue – Inspiration and Our Senses

Objective: The students will have a time for personal reflection on the Grand Canyon (W03/04/05/06/07-S3C1-02; W03/04/05/06/07-S3C2-01)

Procedure:

- Tell students this is their time to focus quietly on the Canyon. Give directions for drawing and listing things they hear or special things they notice.
- Allow 10 minutes for quiet time to draw and write.
- Debrief—what did you see that you hadn't noticed before?

Background Information:

Fossils:
The Kaibab Limestone was deposited by a shallow, warm water sea (100-200' deep) with mild currents. It has been dated at approximately 270 MYO. Most of the fossils found are filter feeders that lived on the sea floor (sponges, brachiopods, corals, bryozoans, crinoids). Sharks teeth have been found as well.

A fossil is any evidence of ancient life. This evidence may be the actual remains, such as bone, teeth, shells or plant tissues; chemically altered remains; or traces of the activities of organisms, such as burrows and tracks. Paleontology is the study of fossils, and scientists who study fossils are paleontologists. Paleontologists use fossils to reconstruct ancient life, using what we know about the present to understand the past and drawing upon the sciences of geology and biology. Paleontology is often confused with archaeology, which is the study of ancient humans and their cultures. The focus of paleontology is the history of life on earth, from its beginnings approximately 3.6 billion years ago, up to the advent of human culture about 10,000 years ago. Except for rare occurrences, fossils are found only in sedimentary rocks.

Upon death, most plant and animal remains are soon digested by bacteria and other living organisms. Thus some of the organic elements of life are recycled to build new organisms. Rare and special circumstances are necessary for any parts or traces of an organism to be preserved as a fossil. Preservation usually requires that an organism or its remains be buried rapidly, be insulated from oxygen and decay-producing organisms, and remain buried and undisturbed. Under even the best of conditions, the preservation of soft parts is exceptionally rare. Usually only hard skeletal elements are preserved as fossils.

Fossils are not always the actual remains of living organisms. Many fossils are just copies called imprints, molds, or casts. Imprints are impressions made by organisms in soft sediment that were preserved when the sediment solidified. Imprints can be traces of an animal's activity, rather than its actual remains. The hardened tracks of animals or the burrows of prehistoric worms in solidified mud are examples of fossil imprints. Molds are made when organisms are totally or partially buried in sediment that hardens into rock. Over time, ground water may dissolve the organisms, leaving cavities shaped like their bodies. Both imprints and molds are mirror images of the organisms. If a mold was later filled with mud or mineral material, the hardened filling is called a cast. It is a reproduction that has the same outer shape as the organism. A cast looks like the organism itself, not like its imprint. Paleontologists make casts of fossil molds by filling them with liquids, such as plaster, that harden.

Geologic Time:
The earth is very old — about 4½ billion years — according to recent estimates. This vast span of time, called geologic time by earth scientists, is difficult to comprehend in the familiar time units of months and years, or even centuries. How then do scientists reckon geologic time, and why do they believe the Earth is so old? The evidence for an ancient Earth is concealed in the rocks that form the Earth's crust and surface. The rocks are not all the same age—or even nearly so—but, like the pages in a long and complicated history, they record the Earth-shaping events and life of the past. The record, however, is incomplete. Many pages, especially in the early parts, are missing and many others are tattered, torn, and difficult to decipher. But enough of the pages are preserved to reward the reader with accounts of astounding episodes which certify that the Earth is billions of years old.
The oldest known rocks on Earth are close to four billion years old. They are found on the shores of Great Slave Lake in Canada's Northwest Territory and in remote areas of Greenland. The rock layers of Grand Canyon range in age from 1800 million years old at the bottom of the canyon to 270 million years old at the top. The metamorphic rocks, found at the bottom of the canyon formed when sedimentary rocks were

subjected to igneous intrusions followed by deep burial. Subsequent flooding by inland seas and windy desert conditions deposited and then reworked the sedimentary rock layers above them.

Grand Canyon has examples of igneous (granite), metamorphic (schists), and sedimentary (limestone, sandstone, and mudstone) layers. The metamorphic (schist) is evidence of heat and pressure from collision of continental plates (aka a "continental car wreck"). When the schist cracked, magma oozed up into those fissures and froze in place (granite). The sedimentary layers are largely deposited by the transgression and regression of ancient seas. The limestones were deposited by shallow seas, sandstones from beach and desert environments, and shales/mudstones from swampy environments.

Igneous rocks are formed from melted rock that has cooled and solidified. When rocks are buried deep within the Earth's crust, they sometimes melt because of the high temperatures. The molten rock (called magma) can then flow upward or even be erupted from a volcano onto the Earth's surface. When magma cools slowly, usually at depths of thousands of feet, crystals grow from the molten liquid, and a course-grained rock forms such as granite. When melted rock cools rapidly, usually at or near the Earth's surface, the crystals are extremely small, and a fine-grained rock results such as basalt.

Sedimentary rocks are formed at the surface of the Earth, either in water or on land. They are layered accumulations of sediments – fragments of rocks, minerals, or animal or plant material. If a layer of sediment is buried beneath overlying rock, the layer becomes compacted and may form a layer of sedimentary rock. The sediment becomes cemented together by minerals and chemicals or is held together by electrical attraction. Sand and gravel on beaches or in river bars look like the sandstone and conglomerate they may become. Compacted and dried mud flats harden into shale. Mud and shells settling on sea floors can cement into limestone.

Metamorphic rocks are formed when sedimentary or igneous rocks are subjected to pressures so intense and/or heat so high that they are completely changed. The process of metamorphism does not melt the rocks, but instead transforms them by reorganizing and changing their crystalline structure. New minerals are created either by rearrangement of mineral components or by reactions with fluids that enter the rocks. Pressure or temperature can even change previously metamorphosed rocks into new types of metamorphic rock.

Plate Tectonics:

The planet earth is made up of three main parts: the crust, the mantle, and the core. The mantle and core are each divided into two parts. Although the core and mantle are about equal in thickness, the core actually forms only 15 percent of the Earth's volume, whereas the mantle occupies 84%. The crust, which is very thin and brittle, makes up the remaining one percent.

Because the crust is accessible to us, its geology has been extensively studied, and therefore much more information is known about its structure and composition than about the structure and composition of the mantle and core. By the large-scale process of plate tectonics, seven large plates and about a dozen smaller ones have moved about on the earth's surface through much of geologic time. The edges of the plates are marked by concentrations of earthquakes and volcanoes. Collisions of plates can produce mountains like the Himalayas, the tallest range in the world. The plates include the crust and part of the upper mantle, and they move over a hot, yielding upper mantle zone at very slow rates of a few centimeters per year. The crust is much thinner under the oceans than under the continents.

The belief that continents have not always been fixed in their present positions was suspected long before the 20th century. However, it was not until 1912 that the idea of moving continents – called Continental

Drift – was first proposed by a German meteorologist named Alfred Wegener. Wegener's theory was based in part on what appeared to him to be the remarkable fit of the South American and African continents, by the occurrence of unusual geologic structures, and of plant and animal fossils found on matching coastlines. Drifting continents also helped explain the evidence of dramatic climate changes on some continents such as tropical plant fossils found in Antarctica. Wegener's proposal was not well received at the time. However, after his death, new evidence from ocean-floor exploration and other studies rekindled interest in Wegener's theory starting in the 1950s and the theory of plate tectonics was born.

One of the exciting advances in geology has been the realization that the continents and substantial parts of the bordering ocean floor have slowly moved with respect to each other and that the outermost layer of the Earth's crust is made up of lithospheric plates. As these thin plates of ocean and continental crust move, they change the positions of the continents; the theory that describes their formation, movement, and destruction is called plate tectonics. The North American plate is slowly moving at the rate of about an inch per year. About 200 million years ago, a supercontinent (called Pangea) linked North and South America, Africa, and Europe.

What drives plate tectonics? Most scientists believe the plates slowly move from the force of convection currents and from the creation of new crust. Below the rigid plates, hot, softened mantle, heated by radioactive decay and residual heat leftover from the formation of the earth, is slowly moving in a circular motion, somewhat like a pot of thick soup when heated to boiling. The heated soup rises to the surface, spreads and begins to cool, and then sinks back to the bottom of the pot where it is reheated and rises again. This cycle is repeated over and over to generate what scientists call a convection cell or convection flow. This circular motion of the mantle carries the continents along in much the same way as a conveyor belt.

What happens to all the new sea floor that is created when magma escapes from the mid-ocean ridge? There are no rocks on the ocean floor older than 200 million years. In addition, our earth is not getting bigger, so for all the new crust that is created, some must be destroyed. This appears to happen where plates collide, and is called plate convergence. When two plates of different densities move toward one another, the denser plate slides under the other and it is forced back into the hot interior of the earth's center. Places where one plate is forced under another are called subduction zones. Earthquakes and volcanoes are common along these convergent plate boundaries. Since oceanic crust is made of denser, heavier material than is continental crust, it (the oceanic plate) dives beneath the lighter continental crust when the two collide.

Downcutting:

Students often know that rivers such as the Colorado River can be muddy. But they may not know that some of the sediment (sand, silt, and clay) that makes the river muddy comes from the riverbed itself and is a result of the river cutting down. The canyon, and all of the formations within it, results directly from weathering and erosion in various forms. The Grand Canyon is one of the world's greatest examples of arid land erosion through layers of stratified rock. For Grand Canyon to form, it needed to be desert and it needed a river starting at a high altitude. The river has cut the canyon by scouring the walls and its bottom with the sediment it carries.

As the river cuts down, it cuts straight through hard layers, then erodes the softer layers more quickly. (This is differential erosion.) As the softer layers erode back, the hard rocks like sandstone eventually collapse due to lack of support. Rain erodes side canyons and canyon walls to make the canyon wider. Freezing and thawing in rock crevices during the winter also erode the canyon walls.

Arizona State Teaching Standards Addressed

The "Dynamic Earth" program addresses the following Arizona Standards:*

Science

SC03/04/05-S1C2-05: Record data in an organized and appropriate format
SC03-S6C1-01: Identify the layers of the Earth: crust, mantle, core (inner and outer)
SC03-S6C1-02: Describe the different types of rocks and how they are formed: metamorphic, igneous, sedimentary
SC03-S6C1-03: Classify rocks based on the following physical properties: color, texture
SC03-S6C1-04: Describe fossils as a record of past life forms
SC04-S1C3-02: Formulate conclusions based upon identified trends in data.
SC04/05-S1C4-01: Communicate verbally or in writing the results of an inquiry.
SC04-S6C2-01: Identify the earth processes that cause erosion.
SC04-S6C2-03: Describe the role that water plays in the following processes that alter the Earth's surface features: erosion, deposition, weathering.
SC04-S6C2-06: Analyze evidence that indicates life and environmental conditions have changed (e.g., tree rings, fish fossils in desert regions, ice cores)
SC05-S1C4-03: Communicate with other groups or individuals to compare the results of a common investigation.
SC06-S1C2-03: Conduct a controlled investigation using scientific process.
SC06/07-S1C2-05: Keep a record of all observations, notes, sketches, questions, and ideas using tools such as written and/or computer logs.
SC06-S1C4-03: Communicate the results of an investigation with appropriate use of qualitative and quantitative information.
SC06-S1C4-05: Communicate the results and conclusion of the investigation.
SC07-S6C1-01: Classify rocks and minerals by the following observable properties: grain, color, texture, hardness
SC07-S6C1-03: Explain the following processes involved in the formation of the earth's structure: erosion, deposition, plate tectonics, volcanism
SC07-S6C1-04: Describe how the rock and fossil record show that environmental conditions have changed over geologic and recent time.
SC07-S6C2-01: Explain the rock cycle.
SC07-S6C2-02: Distinguish the components and characteristics of the rock cycle for the following types of rocks: igneous, metamorphic, sedimentary
SC07-S6C2-03: Analyze the evidence that lithospheric plate movements occur.
SC07-S6C2-05: Relate plate boundary movements to their resulting landforms, including: mountains, faults, rift valleys, trenches, volcanoes.

Language Arts

W03/04/05/06/07-S3C1-02: Write in a variety of expressive forms (e.g., poetry, skit) that may employ: figurative language, rhythm, dialogue, characterization, plot, appropriate format
W03/04/05/06/07-S3C2-01: Record information (e.g., observations, notes, lists, charts, map labels and legends) related to the topic.

National Science Education Standards addressed (Content Standard D):

Grades 5-8: Structure of the earth system and Earth's history

*Although our programs address the curriculum standards, it remains the responsibility of the individual teacher to determine the extent to which the standards have been met based on program content, pre- and post-visit activities, and appropriate evaluation of student learning and understanding.

* Standards last updated in November, 2009